



UNIVERSITI PUTRA MALAYSIA

**DURABILITY STUDY OF PRECAST CONCRETE SANDWICH
PANEL UNDER EXPOSURE TO SEA WATER**

AFTAB AHMAD

FK 2002 31

**DURABILITY STUDY OF PRECAST CONCRETE SANDWICH PANEL UNDER
EXPOSURE TO SEA WATER**

By

AFTAB AHMAD

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfillment of the Requirement for the
Degree of Master of Science**

August 2002



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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August 2002

Chairman: Associate Professor Abdul Aziz Abdul Samad, Ph.D.

Faculty: Engineering

An experimental investigation was conducted to observe and study the behavior of precast concrete sandwich panels in corrosive environment of chloride ion in marine environment. Three different strengths of marine waters were prepared namely one time, three time and six times of the concentration of actual ocean water. Twenty-seven numbers of sandwich panels were casted and nine numbers were placed in each types of solution. Along with that one number of Panel was casted to use as control specimen and left in air for eight months .Two more sandwich panel were used for permeability tests. The study deals with the experimental investigation of panels for their ability to stand in corrosive environment and probability of corrosion in panel reinforcement.

The results obtained were analyzed and observation was made to identify the corrosion probability, location of maximum corrosion and corrosion rate of the sandwich panel reinforcement. Comparative behaviors of the concrete strength variation in different

chloride environment were observed. From the observation of the experimental results it was found that at higher chloride concentration in the environment causes higher corrosion and in the same environment highest corrosion was found along the edges of the precast concrete sandwich panel. There was no critical loss of concrete strength in sandwich panel due to submersion test.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KAJIAN KETAHANAN 'PRECAST CONCRETE SANDWICH PANEL' DI
BAWAH PENDEDAHAN AIR LAUT**

Oleh

AFTAB AHMAD

Ogos 2002

Pengerusi: Profesor Madya Abdul Aziz Abdul Samad, Ph.D.

Fakulti: Pengajian Pendidikan

Satu kajian telah dijalankan untuk memerhati dan mengkaji mengenai kelakuan precast concrete sandwich panels di dalam persekitaran ion kloride yang menghakis di dalam persekitaran air laut

Tiga contoh air laut yang berlainan kepekatan telah disediakan iaitu satu kali, tiga kali dan enam kali ganda kepekatan sebenar air laut. 27 sandwich panel telah dibuat dan 9 telah diendam di dalam setiap satu jenis cecair yang disediakan. Di samping itu juga 1 panel telah dibuat untuk digunakan sebagai ujikaji kawalan dan dibiarkan terdedah kepada udara selama lapan bulan. 2 lagi sandwich panel telah digunakan untuk ujian permeability.

Penyelidikan ini adalah mengenai kajian dan analisa ke atas panel untuk mengetahui kebolehan untuk bertahan di dalam persekitaran yang menghakis dan kebarangkalian hakisan pada besi sandwich panel.

Keputusan yang diperolehi dianalisa dan pemerhatian dibuat untuk mengenalpasti kebarangkalian hakisan, lokasi hakisan yang paling tinggi dan kadar hakisan pada besi sandwich panel. Perbandingan kelakuan konkrit yang berlainan kekuatan di dalam persekitaran kloride yang berlainan telah diterap. Daripada pemerhatian yang telah dibuat daripada keputusan kajian ini, didapati pada kepekatan kloride yang tinggi di dalam persekitaran menyebabkan hakisan yang tinggi dan di dalam persekitaran yang sama, hakisan yang paling tinggi didapati di sepanjang tepi precast konkrit sandwich panel. Tidak ada kehilangan yang kritikal pada kekuatan konkrit di dalam sandwich panel disebabkan oleh ujian perendaman ini.

ACKNOWLEDGEMENTS

The author would like to take this opportunity to express his profound gratitude and thanks to Dr. Abdul Aziz Abdul Samad, his supervisor, for his in valuable guidance ,encouragement ,help and patience throughout this study. His keen interest in this topic and constant suggestions and were the sources and inspiration to the author.

Author wishes to thank to Professor Dr. D.N. Trikha and Prof. .Madya Dr. Waleed Abdul Malik Thanoon for their useful comments and suggestions. Author also would like to send his sincere gratitude to Dr. Mohd. Saleh Jaffer for his help in providing books and journals.

Author wishes to thank the technical staff of Concrete and Structure Laboratory Tuan Hj. Gazali Said , En. Halim ,En. Nayan Din and En. Baharuddin for their kind assistance rendered .

Further , author like to thank to Department of Civil Engineering ,National University of Malaysia (UKM) for allowing him to use the necessary equipments for the research and also to the Jurueteknik Kanan En. Ghani and other technicians for helping him in conducting tests even on Sundays and public holidays.


I certify that an Examination Committee met on 10th August 2002 to conduct the final examination of Aftab Ahmad on his Master of Science thesis entitled “Durability Study of Precast Concrete Sandwich Panel Under Exposure to Sea Water” in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows

Abang Abdullah Abang Ali,
Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Abdul Aziz Abdul Samad, Ph.D.
Associate Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia.
(Member)

D.N. Thrika, Ph.D.
Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia.
(Member)

Waleed Abdul Malik Thanoon, Ph.D.
Associate Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia.
(Member)



SHAMSHER MOHAMAD RAMADILI, Ph.D.
Professor/Deputy Dean
School Of Graduate Studies,
Universiti Putra Malaysia

Date 11 AUG 2002

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Abdul Aziz Abdul Samad, Ph.D.

Associate Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia.
(Chairman)

D.N. Thrika, Ph.D.

Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia.
(Member)

Waleed Abdul Malik Thanoon, Ph.D.

Associate Professor
Department of Civil Engineering
Faculty of Engineering
Universiti Putra Malaysia
(Member)



AINI IDERIS, Ph.D.

Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 9 JAN 2003

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



AFTAB AHMAD

Date : 5/11/02 .

TABLE OF CONTENTS

	Page
ABSTRACT	II
ABSTRAK	IV
ACKNOWLEDGEMENTS	VI
APPROVAL SHEETS	VII
DECLARATION	IX
TABLE OF CONTENTS	IX
LIST OF TABLES	XIV
LIST OF FIGURES	XVII

CHAPTER

1 INTRODUCTION

1.1	General	1
1.2	Corrosion Problem	1
1.3	Corrosion Prediction	2
1.4	Non-Destructive Testing	3
1.5	Precast Concrete Sandwich Panel	5
1.6	Objective	6
1.7	Outline Of The Thesis	6

2 LITERATURE REVIEW

2.0	Trends In Construction Industry	7
2.0.1	Advantage Of Precast Building System	10
2.1	Precast Concrete sandwich Panels-An Introduction	11
2.1.1	Advantage Of precast Concrete sandwich Panel	13
2.1.2	Review On Chloride Attack On Concrete Structures	14
2.2	Durability Aspect Of Precast Concrete Sandwich Panel	16
2.2.1	Mechanism Of Chloride Penetration	17
2.3	Permeability Of Concrete	18
2.3.1	Measurement Of Water Permeability	21



2.4 Chemical Attack On Concrete	22
2.4.1 Sea Water Attack	23
2.4.2 Permeability Code Requirements	28
2.5 Loss Due To Corrosion	28
2.5.1 Fundamentals Of Corrosion	30
2.5.2 Mechanism Of Electro-Chemical Corrosion	31
2.5.2.1 Faraday's Law	32
2.5.2.2 Nernst Equation	32
2.5.2.3 Pourbaix Diagram	34
2.5.2.4 Passivity	35
2.5.2.5 Growth Of Rust Film	36
2.6 Corrosion Of Steel In Concrete	37
2.6.1 Concrete Electrolyte	39
2.7 Transportation Of Water And Chloride In Concrete	42
2.7.1 Chloride Migration	43
2.8 Reinforcing Steel Corrosion	45
2.8.1 Mechanism Of Chloride Attack	46
2.8.2 Threshold Chloride Concentration	48
2.8.3 Rust Volume	51
2.9 Forms Of Corrosion	54
2.9.1 Uniform Corrosion	55
2.9.2 Pitting / Localized Corrosion	55
2.9.3 Crevice Corrosion	57
2.9.4 Galvanic Corrosion	57
2.9.5 Concentration Cell Corrosion	59
2.10 The State Of Pitting Corrosion	60
2.11 The State Of Active Low Potential Corrosion	63
2.12 Techniques Of Corrosion Monitoring Of Steel In Concrete	64
2.13 Corrosion Monitoring And Inspection Technique	65
2.13.1 Visual Inspection	65
2.13.2 Mechanical And Ultrasonic Tests	66
2.13.3 Core Sampling Chemical And Physical Tests	66
2.13.4 Potential Mapping	67
2.13.4.1 Half Cell Potential	68
2.13.4.2 Linear Polarizations Resistance Measurement	69
2.13.5 A.C. Impedance	72
2.13.6 Electro-Chemical Noise	74
2.13.7 Gravimetric Technique (Weight Loss Method)	75
2.14 Techniques For Determination Of Chloride Content	76
2.15 Past And present researches On Corrosion	77
2.16 Need Of the research	78
2.17 The Past Present And Future Of NDT For Evaluation Of Concrete	79



2.17.1 Introduction	80
2.18 Ultrasonic Pulse Velocity Test	82
2.19 Strength Measurement Using NDT	84
2.20 Use Of Ultrasonic For NDT Of Concrete	86
2.21.1 Strength Calibration	87

3 METHODOLOGY

3.1 Experimental Design	89
3.1.1 Specimen Design	90
3.1.2 Material	93
3.2 Experimental Parameter	97
3.3 Properties Of Concrete	99
3.3.1 Concrete	99
3.3.2 Reinforcement	100
3.4 Submersion Test	101
3.4.1 Composition Of Substitute Ocean Water	102
3.5 Half Cell Potential Testing	103
3.6 Chloride Content Test	106
3.6.1 Rapid Chloride Test	107
3.7 Chemical Cleaning Of Corrosion	107
3.8 Ultra Sonic Pulse Velocity Testing	109
3.8.1 Calibration Of PUNDIT For Strength Determination	110
3.9 Moisture Content Test	110
3.10 Initial Surface Absorption Test	111
3.11 Impermeability Of Water Test	112

4 RESULTS AND DISCUSSION

4.1 Initial Surface Absorption Test	114
4.2 Impermeability Test	116
4.3 Moisture Content	120
4.4 Visual Inspection	122
4.5 Chloride Content	128
4.5.1 Effect Of Solution Strength	132
4.5.2 Behavior Of Chloride Ingress	135
4.6 Half-cell Potential Testing	137
4.6.1 Corrosion Probability Contour	137
4.6.2 Half –Cell Potential Propagation	154
4.6.2.1 Effect Of Different Concentration Of Sea Water	154
4.6.3 Interpretation of The Corrosion Potential measurements	160



4.6.4 Average Comparative Half Cell Potential Development	174
4.7 Gravimetric Analysis	185
4.7.1 Rate of Corrosion	186
4.7.2 Loss of steel	187
4.8 Relation Between Av. Half Cell Potential Av. Chloride Content And Loss Of Steel	189
4.9 Ultrasonic Pulse Velocity Testing	192
4.9.1 Comparative Evaluation Of Pulse Velocity In Different Strength Of Sea Water Solution Strength Calibration	194
4.9.2 Relationship Between Pulse Velocity And Cube Strength	197
4.9.3 Determination Of Constants For Estimation Of Concrete Strength	198
4.9.4 In-situ Strength Monitoring in PCSPs	206
4.10 Justification Of The Suitability Of Sandwich Panel	209
 5 CONCLUSION	 213
REFERENCES	214
APPENDIX - I	
APPENDIX - II	
APPENDIX - III	
APPENDIX - IV	
 BIODATA OF THE AUTHOR	

LIST OF TABLE

Table	Page
2 1 Attacking Properties Of Different Chemicals.	23
2 2 Permeability Requirement By Different Code	29
2 3 Some Results Of Chloride Threshold Level	50
2 4 Relative Volume Of Various Corrosion Product	53
2 5 Relation Ship Between Corrosion Resistively Vs Corrosion	66
2 6 Guidance For Interpretation Of Results From Half – Cell Surveys (According To Astm C 876 – 91).	68
2 7 Guidance On Interpretation Of Results Of 3lp And Gecor.	71
2 8 Pulse Velocity Rating For Concrete Quality Grading	88
3 1 Cement Constituent Compounds	93
3 2 Cement Setting Properties	94
3.3 Sieve Analysis Results.	94
3.4 Sieve Analysis Of Fine Aggregate	96
3 5 Test Parameters	97
3 6 Mixture Proportions	98
3 7 Concrete Properties	99
3 8 Mix Design	110
3 9 Composition Of Ocean Water As Per Astm D 1141- 90 (Re-Approved 1992)	102
4 1 ISAT Result After Eight Month	114
4 2 ISAT Result After 28 Days	115



Table	Page
4.3 Typical Recommended Values For The Initial Surface Absorption Test	115
4.4 Impermeability Test Result	116
4.5 Absorbed Volume Of Water During Test	117
4.6 Concrete Permeability Recommendations By Impermeability Code DIN 1048	117
4.7 Effective Porosity Of Sandwich Panel	119
4.8 Moisture Content In Specimen Before Test	121
4.9 Visual Inspection Data Of Sandwich Panel	122
4.10 Typical Checklist For Visual Inspection	125
4.11 Chloride Content Values In Sandwich Panel	131
4.12 Chloride Content In Control Specimen	132
4.13 Chloride Content In Sandwich Panel (W/W Of Cement)	133
4.14 Corrosion Probability Measurements As Per Astm 876-91	160
4.15 Relation Between Half Cell Potential And Probability Of Corrosion	180
4.16 Revised Relation Between Half Cell Potential And Probability Of Corrosion	181
4.17 Half Cell Potential Reading Interpretation Indifferent Type Of Electrode	181
4.18 Gravimetric Analysis Result In 1n Solution	190
4.19 Gravimetric Analysis Result In 3n And 6n Solution	190
4.18 Data Of Average Diameter In 1n Solution	190
4.19 Data Of Average Potential, Loss Of Steel, Corrosion Rate And Reduced Diameter In 3n Solution	190

4.20	Data Of Average Potential, Loss Of Steel, Corrosion Rate And Reduced Diameter In 6n Solution	191
4.21	Concrete Quality And Recommendations From Eminent Researchers	195
4.22	Indirect Pulse Velocity And Calculated Strength In Panel In 1n	200
4.23	Indirect Pulse Velocity And Calculated Strength In Panel In 3n	202
4.24	Indirect Pulse Velocity And Calculated Strength In Panel In 6n	204



LIST OF FIGURES

Figure	Page
2 1 Precast Concrete Sandwich Panel	14
2 2 Relationship Between Crack Width And Corrosion In Different Environment	28
2 3 Pourbaix Diagram For The Feo-H ₂ O System At 25 °C For 10 ⁻⁶ M, Activities Of All Metal Ions	35
2 4 Corrosion Related Cracking In Concrete	51
2 5 Mechanism Of Corrosion Of Steel In Concrete	52
2 6 The Relative Volumes Of Iron And Its Corrosion Reaction Products	52
2 7 Corrosion Possess In Re Bar	60
2 8 Pundit Wire Diagram	83
3 1 Plan And Cross Section Of The Panel	91
3 2 Sieve Analysis Of Coarse Aggregate	95
3 3 Sieve Analysis Of Fine Aggregate	95
3 4 Half-Cell Potential Testing Setup	103
3 5 Half-Cell Potential Meter	104
3 6 Moisture Content Testing Setup	111
3 7 Initial Surface Absorption Test Setup	112
3 8 Impermeability Test Setup	113
4 1 Chloride Content (W/W Of Concrete) Vs Time In 1n, 3n, 6n Solution At 0-15 Mm Depth	129
4 2 Chloride Content (W/W Of Concrete) Vs Time In 1n, 3n, 6n Solution At 15 -30 Mm Depth	129
4 3 Chloride Content (W/W Of Cement) Vs Time In 1n 3n, 6n Solution At 0-15 Mm Depth	130



Figure	Page
4. 4 Chloride Content (W/W Of Cement) Vs. Time In 1n, 3n, 6n Solution At 15-30 Mm Depth	130
4.5 Corrosion Contour Of Panel In 1n Solution After 1 Month	142
4.6 Corrosion Contour Of Panel In 1n Solution After 2 Months	142
4.7 Corrosion Contour Of Panel In 1n Solution After 3 Months	143
4.8 Corrosion Contour Of Panel In 1n Solution After 4 Months	143
4.9 Corrosion Contour Of Panel In 1n Solution After 5 Months	144
4.10 Corrosion Contour Of Panel In 1n Solution After 6 Months	144
4.11 Corrosion Contour Of Panel In 1n Solution After 7 Months	145
4.12 Corrosion Contour Of Panel In 1n Solution After 8 Months	145
4.13 Corrosion Contour Of Panel In 3n Solution After 1 Month	146
4.14 Corrosion Contour Of Panel In 3n Solution After 2 Months	146
4.15 Corrosion Contour Of Panel In 3n Solution After 3 Months	147
4.16 Corrosion Contour Of Panel In 3n Solution After 4 Months	147
4.17 Corrosion Contour Of Panel In 3n Solution After 5 Months	148
4.18 Corrosion Contour Of Panel In 3n Solution After 6 Months	148
4.19 Corrosion Contour Of Panel In 3n Solution After 7 Months	149
4.20 Corrosion Contour Of Panel In 3n Solution After 8 Months	149
4.21 Corrosion Contour Of Panel In 6n Solution After 1 Month	150
4.22 Corrosion Contour Of Panel In 6n Solution After 2 Months	150
4.23 Corrosion Contour Of Panel In 6n Solution After 3 Months	151
4.24 Corrosion Contour Of Panel In 6n Solution After 4 Month	151
4.25 Corrosion Contour Of Panel In 6n Solution After 5 Months	152



Figure	Page
4.26 Corrosion Contour Of Panel In 6n Solution After 6 Months	152
4.27 Corrosion Contour Of Panel In 6n Solution After 7 Months	153
4.28 Corrosion Contour Of Panel In 6n Solution After 8 Months	153
4.29 Half Cell Potential Of Bar 1 In 1n Solution For 8 Months Comparative	156
4.30 Half Cell Potential Of Bar 5 In 1n Solution For 8 Months Comparative	156
4.31 Half Cell Potential Of Bar A In 1n Solution For 8 Months Comparative	157
4.32 Half Cell Potential Of Bar F In 1n Solution For 8 Months Comparative	157
4.33 Half Cell Potential Of Bar 2 In 1n Solution For 8 Months Comparative	158
4.34 Half Cell Potential Of Bar 4 In 1n Solution For 8 Months Comparative	158
4.35 Half Cell Potential Of Bar B In 1n Solution For 8 Months Comparative	159
4.36 Half Cell Potential Of Bar E In 1n Solution For 8 Months Comparative	159
4.37 Half Cell Potential Of Bar 1 In 3n Solution For 8 Months Comparative	164
4.38 Half Cell Potential Of Bar 5 In 3n Solution For 8 Months Comparative	164
4.39 Half Cell Potential Of Bar A In 3n Solution For 8 Months Comparative	165
4.40 Half Cell Potential Of Bar F In 3n Solution For 8 Months Comparative	165
4.41 Half Cell Potential Of Bar 2 In 3n Solution For 8 Months Comparative	166
4.42 Half Cell Potential Of Bar 4 In 3n Solution For 8 Months Comparative	166
4.43 Half Cell Potential Of Bar B In 3n Solution For 8 Months Comparative	167
4.44 Half Cell Potential Of Bar E In 3n Solution For 8 Months Comparative	167
4.45 Half Cell Potential Of Bar 1 In 6n Solution For 8 Months Comparative	168
4.46 Half Cell Potential Of Bar 5 In 6n Solution For 8 Months Comparative	168
4.47 Half Cell Potential Of Bar A In 6n Solution For 8 Months Comparative	169

Figure	Page
4.48 Half Cell Potential Of Bar F In 6n Solution For 8 Months Comparative	169
4.49 Half Cell Potential Of Bar 2 In 6n Solution For 8 Months Comparative	170
4.50 Half Cell Potential Of Bar 4 In 6n Solution For 8 Months Comparative	170
4.51 Half Cell Potential Of Bar B In 6n Solution For 8 Months Comparative	171
4.52 Half Cell Potential Of Bar E In 6n Solution For 8 Months Comparative	171
4.53 Half Cell Potential Of Control In Air After 28 Days	172
4.54 Half Cell Potential Of Control In Air After 8 Months	173
4.55 Average Half Cell Potential In Bar I In 1n, 3n, 6n Solution	174
4.56 Average Half Cell Potential In Bar 5 In 1n, 3n, 6n Solution	176
4.57 Average Half Cell Potential In Bar A In 1n, 3n, 6n Solution	176
4.58 Average Half Cell Potential In Bar F In 1n, 3n, 6n Solution	177
4.59 Average Half Cell Potential In Bar 2 In 1n, 3n, 6n Solution	177
4.60 Average Half Cell Potential In Bar 4 In 1n, 3n, 6n Solution	178
4.61 Average Half Cell Potential In Bar B In 1n, 3n, 6n Solution	178
4.62 Average Half Cell Potential In Bar E In 1n, 3n, 6n Solution	179
4.63 % Loss Of Steel Vs Half Cell Potential	183
4. 64 Rate Of Corrosion Vs. Time	186
4. 65 Percentage Loss Of Steel Vs. Time	187
4 .66 Reduced Diameter (Mm) Vs. Time	188
4. 67 Average Chloride Content Vs Average. Half Cell Potential	192
4. 68 Pulse Velocity In Sandwich Panel In 1n Solution	193
4. 69 Pulse Velocity In Sandwich Panel In 3n Solution	193

Figure	Page
4.70 Pulse Velocity In Sandwich Panel In 6n Solution	194
4.71 Standerdisation Of. Pulse Velocity Vs . Cube Strength.	197
4.72 Strength Monitoring In 1n Solution	206
4.73 Strength Monitoring In 3n Solution	207
4.74 Strength Monitoring In 6n Solution	207



CHAPTER 1

INTRODUCTION

1.1 General

Concrete is an ubiquitous material. Concrete is the combination of cement acting as a binder and non-reactive or partially reactive aggregate fillers. It is normally considered protective to the reinforced steel embedded in it because of the alkalinity produced during the hydration reactions that contained in the pore solution. Nevertheless, corrosion of reinforcing steel in concrete occurs as a result of many factors, including chloride ion contamination, carbonation of the concrete, etc. These result in a build-up of corrosion products, which being more voluminous than the embedded metal. It introduces significant tensile and compressive loads on the concrete, which leads to cracking, disbandment and ultimately, spalling of the concrete cover. Cracking and disbandment lead to further corrosion, which can compromise the life of the entire structure. The problem involves reinforced concrete structures, such as coastal concrete structures, bridges, etc.

1.2 Corrosion Problem

The corrosion of reinforcing steel bars (rebars) in concrete is a growing problem affecting the integrity of a vast number of structures. The reinforcing steel is embedded in the concrete, which initially provides an alkaline environment conducive to surface passivation. Under these conditions, metal dissolution takes place at an extremely low rate.

However, depassivation of the steel surface can take place if chlorides from seawater penetrate through the concrete cover and reach the rebar.

Depassivation can also result from penetration of a carbonation front through the concrete as a result of exposure to atmospheric carbon dioxide. The locally active steel surface behaves predominantly as an anode while the entire bar may serve as a cathode. The main cathodic reaction is thought to be the reduction of oxygen, which is transported to the metal surface through the concrete cover. Metal ions dissolved at the anodic reaction form the corrosion products, which are expected to occupy a significant amount of volume larger than the initial metal. Cracking and spalling of the concrete cover eventually follow and require expensive repairs or replacement of the structure.

Substructure members and pilings supporting marine bridges are frequently constructed using steel reinforced concrete. In typical installations, the columns are partially submerged in seawater, so that a region of high chloride ion concentration builds up in the splash zone just above the high water line. Passivity breakdown at the surface of the steel embedded in this region and below water; results in a subsequent active corrosion of the steel and shortening the useful life of the element.

1.3 Corrosion Prediction

There are few quantitative studies aimed to predict the distribution of potential in re-bars. Moreover, these predictions cannot be confirmed easily by experimental measurements.

This is because the polarization conditions at the steel surface are complicated by slow transport of oxygen and corrosion products. There is a need to predict the steel's potential in concrete.

Steel in concrete is a clear example of a half-cell. It is a metal surrounded by an electrolyte. The potential of such a half-cell can only be measured relative to another half-cell, which is known as a reference half-cell or a reference electrode. In 1980, ASTM issued its standard C876-77, which describes the test procedure for measuring the potentials of reinforcing steel in concrete. The placement of a reference electrode on the concrete surface and the measurement of the potential difference from the reference electrode and the embedded steel. It allows to measure the potential difference, which indicates the state of corrosion of steel.

The potential of steel reinforcement can be used to assess the probability of corrosion at the time of measurement.

1.4 Non-destructive Testing

In a short span of time, nondestructive testing, especially, Ultrasonic Pulse Velocity (UPV) testing has achieved its importance in quality assessment of hardened concrete's strength and durability evaluation of existing concrete structure. For instance, when investigating width and depth of the crack in concrete, nondestructive (UPV) test method is the only one that can provide reasonable answers. The primary cause of failure in concrete structure in